[Name of Document]   SPECIFICATION

[Title of the Invention]   DRIVING METHOD FOR ELECTRO-OPTICAL DEVICE,

ELECTRO-OPTICAL DEVICE, AND ELECTRONIC APPARATUS

[Claims]

[Claim 1]   A driving method for an electro-optical device which comprises, at an intersection of a scanning line and a data line, an electro-optical element, a driving transistor for driving the electro-optical element, and a switching transistor for controlling the driving transistor, the driving method comprising:

a setting step of supplying a first on-signal to the switching transistor via the scanning line, and of supplying a set signal for selecting a conducting state or a non-conducting state of the driving transistor to the driving transistor via the data line and the switching transistor in accordance with a period for which the first on-signal is supplied; and

a resetting step of supplying a second on-signal to the switching transistor via the scanning line, and of supplying a reset signal for selecting the non-conducting state of the driving transistor to the driving transistor via the data line and the switching transistor in accordance with a period for which the second on-signal is supplied.

[Claim 2]   A driving method for an electro-optical device according to claim 1, wherein a horizontal scanning period comprises a first sub horizontal scanning period for performing the setting step and a second sub horizontal scanning period for performing the resetting step.

[Claim 3]   A driving method for an electro-optical device according to

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claim 1, wherein the setting step is performed in a first horizontal scanning period, and the resetting step is performed in a second horizontal scanning period.

[Claim 4] A driving method for an electro-optical device according to any one of claims 1 to 3, wherein a gray-scale is obtained by performing a plurality of set-reset operations, each set-reset operation comprising the setting step and the resetting step.

[Claim 5] A driving method for an electro-optical device according to claim 4, wherein a time interval between the setting step and the resetting step is different for each of the plurality of set-reset operations.

[Claim 6] A driving method for an electro-optical device according to one of claims 4 and 5, wherein the time interval between the setting step and the resetting step for each of the plurality of set-reset operations is completely different from each other, and the ratio of time intervals for the plurality of set-reset operations is set to be about $1:2: .. :2^n$ (n is an integer of one or more) based on the minimum time interval.

[Claim 7] A driving method for an electro-optical device according to any one of claims 1 to 6, wherein the set signal is a signal for setting the conducting state for the driving transistor rather than the signal for selecting the conducting state or the non-conducting state of the driving transistor.

[Claim 8] A driving method for an electro-optical device according to any one of claims 1 to 7, wherein the electro-optical element comprises

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an organic electro-luminescence element.

[Claim 9] An electro-optical device driven by the driving method set forth in any one of claims 1 to 8.

[Claim 10] An electro-optical device including, at an intersection of a scanning line and a data line, an electro-optical element, a driving transistor for driving the electro-optical element, and a switching transistor for controlling the driving transistor, the electro-optical device comprising a drive circuit for generating a signal for setting the switching transistor to be an on-state or an off-state, and for generating a signal for setting or resetting the driving transistor in accordance with the signal for setting the switching transistor to be the on-state or the off-state.

[Claim 11] An electro-optical device including, at an intersection of a scanning line and a data line, an electro-optical element, a driving transistor for driving the electro-optical element, and a switching transistor for controlling the driving transistor, the electro-optical device comprising:

a scanning line driver for supplying a signal for setting the switching transistor to be an on-state or an off-state to the scanning line; and

a data line driver for supplying a signal for setting or resetting the driving transistor to the data line in accordance with an operation of the scanning line driver.

[Claim 12] An electro-optical device comprising, at an intersection of a scanning line and a data line, an electro-optical element, a

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driving transistor for driving the electro-optical element, and a switching transistor for controlling the driving transistor,

wherein an on-signal for performing a setting step of setting the electro-optical element and a resetting step of resetting the electro-optical element is supplied to the switching transistor via the scanning line.

[Claim 13] An electro-optical device according to any one of claims 10 to 12, wherein the electro-optical element comprises an organic electro-luminescence element.

[Claim 14] An electronic apparatus in which the electro-optical device set forth in any one of claims 9 to 13 is installed.

[Detailed Description of the Invention]

[Technical Field of the Invention]

The present invention relates to a driving method for an organic electro-luminescence display device, a driving method for an electro-optical device suitable for use with an organic electro-luminescence display device the electro-optical device, and an electronic apparatus provided with such an electro-optical device.

[Description of the Related Art]

Attention is being given to organic electro-luminescence (electric-field luminescence) display devices using organic materials as luminescent materials of luminescent elements since they have a wide viewing angle, and will potentially meet market demands, i.e., demands for thinner, lighter, smaller, and lower power-consuming display devices.

Unlike conventional liquid crystal display devices, in organic

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electro-luminescence display devices, the luminescence state of the luminescent element must be controlled by a current. One such control method is the conductance control method (T. Shimoda, M. Kimura, et al., Proc. Asia Display 98, 217; M. Kimura, et al., IEEE Trans. Ele. Dev. 46, 2282 (1999); M. Kimura, et al., Proc. IDW 99, 171; and M. Kimura et al., Dig. AM-LCD 2000, to be published). In this method, the luminescence state of the luminescent element is controlled by a current value, which is an analog value, and more specifically, it is controlled by changing the potential applied to a gate electrode of a driving transistor for driving the luminescent element. When thin-film transistors having different current characteristics are used, however, the difference in the current characteristics of the individual transistors may sometimes directly result in the non-uniformity in the luminescence state of the luminescent elements.

Accordingly, the area ratio gray-scale method (M. Kimura, et al., Proc. Euro Display '99 Late-News Papers, 71, Japanese Unexamined Patent Application Publication No. 11-073158, M. Kimura, et al., Proc. IDW 99,171, M. Kimura, et al, J. SID, to be published; and M. Kimura, et al., Dig. AM-LCD 2000 to be published) has been proposed. In the area ratio gray-scale method, unlike the above-mentioned conductance control method, the luminescence state of the luminescent elements is controlled without using a luminescence state at an intermediate luminance. More specifically, in this method, a gray-scale is displayed as follows. Pixels disposed in a matrix are divided into a plurality of sub-pixels, and it is determined whether the luminescent elements contained in the

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sub-pixels are either in a complete luminescence state or a complete non-luminescence state. Then, among the plurality of sub-pixels, the total area of the sub-pixels in the complete luminescence state is changed. In the area ratio gray-scale method, it is not necessary to set an intermediate current value corresponding to the luminescence state of the intermediate luminance. Accordingly, the influence of the current characteristics of the transistors for driving the luminescent elements can be reduced, thereby achieving a uniform image quality. In this method, however, the number of gray-scale levels is restricted by the number of sub-pixels. For a greater number of gray-scale levels, pixels must be divided into a greater number of sub-pixels, which makes the pixel structure complicated.

Accordingly, the time ratio gray-scale method (M. Kimura, et al., Proc. IDW 99, 171; M. Kimura, et al., Dig. AM-LCD 2000, to be published; M. Mizukami, et al., Dig. SID 2000, 912; and K. Inukai, et al., Dig. SID 2000,924) has been proposed.

In the time ratio gray-scale method, the representation of the gray-scale is implemented by changing the period for which the luminescent elements in one frame are in the complete luminescence state. Accordingly, unlike the area ratio gray-scale method, it is not necessary to provide many sub-pixels for obtaining a greater number of gray-scale levels, and also, the time ratio gray-scale method can be used together with the area ratio gray-scale method. Thus, it is expected that the time ratio gray-scale method will be a promising method for digitally displaying a gray-scale.

[Problems to be Solved by the Invention]

However, in the SES (Simultaneous-Erasing-Scan) time ratio gray-scale method, which is reported in "K. Inukai, et al., Dig. SID 2000,924", in addition to the scanning lines, reset lines are required, and thus, the luminescence area is disadvantageously reduced. Accordingly, a first object of the present invention is to provide a method for implementing the representation of a gray-scale of an electro-optical device without reset lines, and in particular, to provide a method for implementing the representation of the gray-scale of an electro-optical device, such as an organic electro-luminescence display device, according to the time ratio gray-scale method. A second object of the present invention is to provide an electro-optical device driven by the above-described driving method.

[Means for Solving the Problems]

In order to achieve the first object, a first driving method for an electro-optical device according to the present invention is a driving method for an electro-optical device which includes, at an intersection of a scanning line and a data line, an electro-optical element, a driving transistor for driving the electro-optical element, and a switching transistor for controlling the driving transistor. The driving method includes: a setting step of supplying a first on-signal to the switching transistor via the scanning line, and of supplying a set signal for selecting a conducting state or a non-conducting state of the driving transistor to the driving transistor via the data line and the switching transistor in accordance with a period for which the first

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on-signal is supplied; and a resetting step of supplying a second on-signal to the switching transistor via the scanning line, and of supplying a reset signal for selecting the non-conducting state of the driving transistor to the driving transistor via the data line and the switching transistor in accordance with a period for which the second on-signal is supplied.

With this arrangement, since the on-signal is supplied to the switching transistor via the scanning line, and the set signal or the reset signal is supplied via the data line in accordance with the on-signal, the state of the electro-optical element can be selected withouta reset line. In this specification, the electro-optical element and the electro-optical device respectively indicate an element and a device in which the luminescence state or the optical characteristic is electrically controlled. Specific examples of the electro-optical device include display devices, such as luminescence display devices, liquid crystal display devices, and electrophoretic display devices.

Throughout the specification, the on-signal indicates a signal for selecting the on-state of the switching transistor. Also, throughout the specification, the "step of supplying a first on-signal to the switching transistor via the scanning line, and of supplying a set signal for selecting a conducting state or a non-conducting state of the driving transistor to the driving transistor via the data line and the switching transistor in accordance with a period for which the first on-signal is supplied" is defined as the "setting step". The "step of supplying a second on-signal to the switching transistor via the

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scanning line, and of supplying a reset signal for selecting the non-conducting state of the driving transistor to the driving transistor via the data line and the switching transistor in accordance with a period for which the second on-signal is supplied" is defined as the "resetting step". The first on-signal and the second on-signal are not necessarily two consecutive on-signals, and may be discretely set.

A second driving method for an electro-optical device according to the present invention is characterized in that the horizontal scanning period may include a first sub horizontal scanning period for performing the setting step and a second sub horizontal scanning period for performing the resetting step. It is necessary that the first sub horizontal scanning period and the second sub horizontal scanning period be different from each other. Accordingly, the setting step and the resetting step do not overlap with each other. The first sub horizontal scanning period and the second sub horizontal scanning period are not necessarily two consecutive horizontal scanning periods, and may be discretely set. It is not necessary that the first sub horizontal scanning period and the second sub horizontal scanning period be included in the same horizontal scanning period, and may be included in different horizontal scanning periods.

According to a third driving method for an electro-optical device of the present invention, in the above-described driving method for an electro-optical device, the setting step may be performed in a first horizontal scanning period, and the resetting step may be performed in a second horizontal scanning period. It is necessary that the first sub

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horizontal scanning period and the second sub horizontal scanning period
be different from each other. Accordingly, the setting step and the
resetting step do not overlap with each other. The setting step and the
resetting step do not have to be performed throughout the whole
horizontal scanning period, and may be partially performed in the
horizontal scanning period. The first sub horizontal scanning period
and the second sub horizontal scanning period are not necessarily two
consecutive horizontal scanning periods, and may be discretely set.

According to a fourth driving method for an electro-optical device
of the present invention, in the above-described driving method for an
electro-optical device, a gray-scale may be obtained by performing a
plurality of set-reset operations, each set-reset operation including
the aforementioned setting step and the resetting step. Accordingly,
the state of the electro-optical device is selected in the setting step,
and remains the same until the resetting step is performed. Thus, by
performing a plurality of set-reset operations, a gray-scale can be
obtained. Throughout the specification, the set-reset operation is
defined as an operation including the above-described setting step and
the resetting step.

According to a fifth driving method for an electro-optical device
of the present invention, in the above-described driving method for an
electro-optical device, a time interval between the setting step and the
resetting step may be different for each of the plurality of set-reset
operations.

According to a sixth driving method for an electro-optical device

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of the present invention, in the above-described driving method for an electro-optical device, the time interval between the setting step and the resetting step for each of the plurality of set-reset operations may be completely different from each other, and the ratio of time intervals for the plurality of set-reset operations may be about $1:2: \ldots :2^n$ (n is an integer of one or more). For example, if two set-reset operations with a time interval ratio of 1:2 are performed, four gray-scale levels, i.e., 0, 1, 2, 3, can be displayed. If two set-reset operations with a time interval ratio of 1:1 are performed, three gray-scale levels, i.e., 0, 1, and 2 can be displayed. That is, in this driving method for an electro-optical device, a maximum number of gray-scale levels can be obtained by a minimum number of set-reset operations. The time interval ratio does not have to be precisely $1:2: \ldots :2^n$ (n is an integer of one or more), and may be sufficient to such a degree to satisfy a required gray-scale precision.

According to a seventh driving method for an electro-optical device of the present invention, in the above-described driving method for an electro-optical device, the set signal may be a signal for setting the driving transistor to the conducting state rather than the signal for selecting the conducting state or the non-conducting state of the driving transistor. This means that an intermediate conducting state other than the two states, i.e., the conducting state and the non-conducting state, of the driving transistor is selectable. This can be implemented by the set signal provided as a voltage having three or more consecutive or discrete values. This driving method is effective for

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implementing many gray-scale levels.

According to an eighth driving method for an electro-optical device of the present invention, in the above-described driving method for an electro-optical device, the electro-optical element may be an organic electro-luminescence element. Generally, the power consumption of the organic electro-luminescence element is advantageously low.

A first electro-optical device of the present invention is driven by the above-described driving method for an electro-optical device.

A second electro-optical device of the present invention is an electro-optical device including, at an intersection of a scanning line and a data line, an electro-optical element, a driving transistor for driving the electro-optical element, and a switching transistor for controlling the driving transistor. The electro-optical device includes a drive circuit for generating a signal for setting the switching transistor to be an on-state or an off-state, and for generating a signal for setting or resetting the driving transistor in accordance with the signal for setting the switching transistor to be the on-state or the off-state.

A third electro-optical device of the present invention is an electro-optical device including, at an intersection of a scanning line and a data line, an electro-optical element, a driving transistor for driving the electro-optical element, and a switching transistor for controlling the driving transistor. The electro-optical device includes: a scanning line driver for supplying a signal for setting the switching transistor to be an on-state or an off-state to the scanning

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line; and a data line driver for supplying a signal for setting or resetting the driving transistor to the data line in accordance with an operation of the scanning line driver.

A fourth electro-optical device of the present invention is an electro-optical device including, at an intersection of a scanning line and a data line, an electro-optical element, a driving transistor for driving this electro-optical element, and a switching transistor for controlling this driving transistor. In the fourth electro-optical device, an on-signal for performing a setting step of setting the electro-optical element and a resetting step of resetting the electro-optical element is supplied to the switching transistor via the scanning line. In the above description, the definitions of the setting step and the resetting step are substantially similar to those of the setting step and the resetting step set forth in claim 1. Accordingly, the first through fourth electro-optical devices of the present invention do not require a reset line for performing the time ratio gray-scale method. Advantageously, therefore, it is possible to ensure a sufficient area for the electro-optical element. If more gray-scale levels are required, the time ratio gray-scale method can be employed with the area ratio gray-scale method when sub pixels are provided in the pixels of the electro-optical device.

According to a fifth electro-optical device of the present invention, in the above-described electro-optical device, the electro-optical element may be an organic electro-luminescence element.

A first electronic apparatus of the present invention is an

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electronic apparatus in which the above-described electro-optical device is installed.

[Description of the Embodiments]

Preferred embodiments of the present invention are described below.

A basic circuit used in an embodiment of the present invention includes a poly-crystal silicon thin-film transistor formed by a low-temperature process at 600°C or lower (low-temperature poly-Si TFT). The low-temperature poly-Si TFT can be formed on a large, inexpensive glass substrate, and can integrate a driving circuit on a panel, and accordingly, it is suitable for manufacturing an electro-optical device. Additionally, the low-temperature poly-Si TFT is small, but has a high current supplying power. Accordingly, it is suitable for use in a high-precision current luminescence display device. The present invention is also applicable to an electro-optical device driven by other types of transistors, such as an amorphous silicon thin-film transistor (a-Si TFT), a silicon-based transistor, and an organic thin-film transistor using an organic semiconductor.

The equivalent circuit of one pixel of an electro-optical device according to an embodiment of the present invention is shown in Fig. 1. In this embodiment, as the electro-optical element, a luminescent element is used. In this electro-optical device, a scanning line (S1), a data line (D1), and a power line (V) are formed, and a luminescent element (L11), a driving transistor (DT11) for driving the luminescent element (L11), a switching transistor (ST11) for controlling this driving transistor (DT11), and a capacitor (C11) are provided at the

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intersection of the scanning line (S1) and the data line (D1). One end

of the luminescent element (L11) is connected to an anode (A). The

driving transistor (DT11) is p-type. Accordingly, the driving

transistor (DT11) enters a conducting state selected by a low-potential

data signal to cause the luminescent element (L11) to be in the

luminescence state. In contrast, the driving transistor (DT11) enters a

non-conducting state selected by a high-potential data signal to cause

the luminescent element (L11) to be in the non-luminescence state. In

the pixel equivalent circuit shown in Fig. 1, the switching transistor

(ST11) is n-type, and the driving transistor (DT11) is p-type. However,

this is not a limitation to implement the present invention.

Fig. 2 illustrates wiring and a pixel arrangement of an electro-

optical device according to an embodiment of the present invention.

Pixels are arranged in a matrix by a plurality of scanning lines (S1,

S2, ...) and a plurality of data lines (D1, D2, ...), and a plurality

of pixels are formed at corresponding intersections of the scanning

lines and the data lines. For example, a pixel 11 is provided at the

intersection of S1 and D1. Basically, the pixel includes a switching

transistor (ST11), a capacitor (C11), a driving transistor (DT11), and a

luminescent element (L11), such as those shown in Fig. 1. However, the

pixel may include a plurality of sub-pixels. A power line is not shown

in Fig. 2.

Fig. 3 illustrates a driving method for an electro-optical device

according to an embodiment of the present invention. In this driving

method, a horizontal scanning period (H) comprises two sub horizontal

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scanning periods (SH1 and SH2). The scanning signal and the data signal are either a high-potential signal or a low-potential signal. A first scanning signal SS(S1) is supplied to the first scanning line (S1). A second scanning signal SS(S2) is supplied to the second scanning line (S2). A third scanning signal SS(S3) is supplied to the third scanning line (S3). A first data signal DS(D1) is supplied to the first data line (D1). A second data signal DS(D2) is supplied to the second data line (D2). A third data signal DS(D3) is supplied to the third data line (D3). In DS(D1), DS(D2), and DS(D3), the hatched portions indicate a set signal, while the other portions indicate a reset signal. A low-potential data signal, which causes the luminescent element to be in the luminescence state, is supplied as the set signal. For causing the luminescent element to be in the non-luminescence state, a high-potential set signal is supplied.

In the sub horizontal scanning period SH1 of the horizontal scanning period H1, the luminescent element is set to be in the luminescence state or the non-luminescence state by a setting step of "supplying a first on-signal to the switching transistor (ST11) via the scanning line (S1), and of supplying the set signal for selecting the conducting state or the non-conducting state of the driving transistor (DT11) to the driving transistor (DT11) via the data line D1 and the switching transistor (ST11) in accordance with the period for which the first on-signal is supplied". In the sub horizontal scanning period SH2 of the horizontal scanning period H2, the luminescent element is set to be in the non-luminescence state by a resetting step of "supplying a

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second on-signal to the switching transistor (ST11) via the scanning
line (S1), and of supplying the reset signal for selecting the non-
conducting state of the driving transistor (DT11) to the driving
transistor (DT11) via the data line D1 and the switching transistor
(ST11) in accordance with the period for which the second on-signal is
supplied". According to the above-described setting step and resetting
step, the luminescence period (E1) of the first-row and first-column
pixel 11 is set. It may take some time for the transistor or the
luminescent element to respond to the corresponding signal. Accordingly,
as shown in Fig. 3, the start time and the end time of the luminescence
period may be displaced from the start of the setting step and the start
of the resetting step, respectively. In Fig. 3, the period for which
the first on-signal is supplied coincides with the period for which the
set signal is supplied, and the period for which the second on-signal is
supplied coincides with the period for which the reset signal is
supplied. However, depending on the circumstances of the use or the
specifications, the on-signal does not always have to coincide with the
set signal or the reset signal.

The setting step and the resetting step for the subsequent scanning
line (S2) are performed such that they are displaced from those for the
scanning line (S1). As shown in Fig. 3, they are preferably performed
at times closest to those for the scanning line (S1). Thereafter,
similarly, the setting step and the resetting step are performed for the
third scanning line (S3) and the subsequent scanning lines. Then, one
vertical scanning period is finished. For the subsequent vertical

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scanning period, the setting step and the resetting step are similarly performed for each scanning line. The ratio of the luminescence periods E1, E2, and E3 is about 1:2:4. As a result, eight gray-scale levels, such as 0, 1, 2, 3, 4, 5, 6, and 7, are obtained.

In the embodiment shown in Fig. 3, one horizontal scanning period is divided into two sub horizontal scanning periods. However, as shown in Fig. 4, the setting step and the resetting step may be set in units of horizontal scanning periods. In Fig. 4, the period of the setting step and the period of the resetting step respectively coincide with the horizontal scanning period. However, neither the setting step nor the resetting step has to be performed throughout the whole horizontal scanning period.

Among a plurality of set-reset operations, a set-reset operation may be partially or wholly performed during the same horizontal scanning period. Such an embodiment is shown in Fig. 5. In this embodiment, the setting step and the resetting step are performed in units of sub horizontal scanning periods (SH) which are obtained by dividing the horizontal scanning period (H) into four. The first set-reset operation is performed in the same horizontal scanning period. In the second and the subsequent set-reset operations, the horizontal scanning period of the sub horizontal scanning period for which the setting step is performed is different from that of the sub horizontal scanning period for which the resetting step is performed. In each vertical scanning period, upon completion of the horizontal scanning period for the first scanning line (S1), the set-reset operation is started for the second

scanning line (S2). Thereafter, the set-reset operation is similarly formed for the third scanning line (S3) and the subsequent scanning lines.

In any of the driving methods for the electro-optical devices shown in Figs. 3 through 5, the set-reset operations are sequentially performed such that the time interval between the setting step and the resetting step is increased. However, the set-reset operations do not have to be performed in this order, and it can be performed according to the circumstances of the use or the specifications. As in the driving methods for the electro-optical devices shown in Figs. 3 through 5, for simplicity of a peripheral circuit system, such as a data line driver, the reset signal is preferably supplied at regular intervals. However, it is not essential that the reset signal be supplied at regular intervals, and the timing for supplying the on-signal and the reset signal to the switching transistor can suitably be set according to the desired luminescence period.

Fig. 6 illustrates current characteristics of the luminescent element according to an embodiment of the present invention. The horizontal axis represents control potential (Vsig) supplied to the gate electrode of the driving transistor, and the vertical axis designates current value (IIep) of the organic electro-luminescence device. The current value and the luminance of the organic electro-luminescence device are substantially proportional to each other. Thus, it can be considered that the vertical axis also indicates the luminance. In this embodiment, it is preferable that the organic electro-luminescence

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device is unambiguously controlled to be either in the on state or the off state. When the electro-luminescence device is unambiguously in the on state or in the off state, the current value (IIep) is substantially constant. Thus, a variation in the transistor characteristics does not change the current value of the luminescent element, and accordingly, the luminance substantially becomes uniform. Therefore, the image quality can be uniform.

Fig. 7 illustrates a manufacturing process for a thin-film transistor for use in the electro-optical device according to an embodiment of the present invention. Amorphous silicon is first formed on a glass substrate 1 by PECVD using SiH_4 or by LPCVD using Si_2H_6. The amorphous silicon is poly-crystallized by a laser, such as an excimer laser, or by solid-phase growth, thereby forming a poly-crystalline silicon layer 2 (Fig. 7(a)). After the poly-crystalline silicon layer 2 is patterned, a gate insulating film 3 is formed, and gate electrodes 4 are further formed (Fig. 7(b)). An impurity, such as phosphorus or boron, is implanted into the poly-crystalline silicon layer 2 by the gate electrodes 4 according to a self-alignment process so as to form MOS transistors 5a and 5b. The MOS transistors 5a and 5b are a p-type transistor and an n-type transistor, respectively. After a first interlayer insulating film 6 is formed, contact holes are formed, and a source electrode and a drain electrode 7 are formed (Fig. 7(c)). Then, after a second interlayer insulating film 8 is formed, contact holes are formed, and a pixel electrode 9 comprising ITO is formed (Fig. 7(d)).

Fig. 8 illustrates a manufacturing process for pixels used in the

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electro-optical device according to an embodiment of the present invention. First, an adhesion layer 10 is formed, and an opening corresponding to a luminescent region is formed. An interlayer 11 is then formed, and an opening is formed (Fig. 8(a)). Then, the wettability of the substrate surface is controlled by performing plasma processing using, for example, oxygen plasma or CF_4 plasma. Subsequently, an electron-hole implantation layer 12 and a luminescent layer 13 are formed according to a liquid-phase process, such as a spin coating, squeegee, or ink-jet process, or a vacuum process, such as sputtering or deposition. An anode 14 containing metal, such as aluminum, is then formed. Finally, a sealing layer 15 is formed. Thus, an organic electro-luminescence device is manufactured (Fig. 8(b)). The roles of the adhesion layer 10 are to improve the adhesion between the substrate and the interlayer 11 and also to obtain an accurate luminescence area. The roles of the interlayer 11 are to reduce the parasitic capacitance by separating the gate electrodes 4, the source electrodes, and the drain electrodes 7 from the anode 14, and also to perform precise patterning by controlling the surface wettability when forming the electron-hole implantation layer 12 and the luminescent layer 13 by a liquid-phase process.

Some examples of electronic apparatuses using the above-described electro-optical device are described below. Fig. 9 is a perspective view illustrating the configuration of a mobile personal computer to which the above-described electro-optical device is applied. In Fig. 9, a personal computer 1100 includes a main unit 1104 provided with a

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keyboard 1102, and a display unit 1106. The display unit 1106 is provided with the above-described electro-optical device 100.

Fig. 10 is a perspective view illustrating the configuration of a cellular telephone having a display unit to which the aforementioned electro-optical device 100 is applied. In Fig. 10, a cellular telephone 1200 includes, not only a plurality of operation buttons 1202, but also the above-described electro-optical device 100 together with an earpiece 1204 and a mouthpiece 1206.

Fig. 11 is a perspective view illustrating the configuration of a digital still camera having a finder to which the above-described electro-optical device 100 is applied. Fig. 11 also schematically illustrates the connection of the digital still camera with external devices. In a regular camera, a film is exposed to light by an optical image of a subject. In a digital still camera 1300, however, an optical image of a subject is photoelectrically converted by an image pickup device, such as a CCD (Charge Coupled Device) so as to generate an imaging signal. On the rear surface of a casing 1302 of the digital still camera 1300, the aforementioned electro-optical device 100 is provided to display the subject based on the imaging signal obtained by the CCD. That is, the electro-optical device 100 serves as a finder for displaying the subject. On the observation side (on the reverse surface in Fig. 11) of the casing 1302, a photodetector unit 1304 including an optical lens and a CCD is disposed.

A photographer checks the subject displayed on the electro-optical device 100 and presses a shutter button 1306. Then, an imaging signal

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obtained by the CCD is transferred to and stored in a memory of a circuit board 1308. In this digital still camera 1300, a video signal output terminal 1312 and a data communication input/output terminal 1314 are provided on the side surface of the casing 1302. Then, as shown in Fig. 11, a television monitor 1430 and a personal computer 1440 are connected to the video signal output terminal 1312 and the data communication input/output terminal 1314, respectively, as required. The imaging signal stored in the memory of the circuit board 1308 is output to the television monitor 1430 or the personal computer 1440 by a predetermined operation.

Electronic apparatuses to which the electro-optical device 100 of the present invention is applicable include, not only the personal computer shown in Fig. 9, the cellular telephone shown in Fig. 10, and the digital still camera shown in Fig. 11, but also a liquid crystal television, a view-finder-type or direct-view-type video cassette recorder, a car navigation system, a pager, an electronic diary, a calculator, a word processor, a workstation, a videophone, a POS terminal, a device provided with a touch panel, for example. It is needless to say that the above-described electro-optical device 100 is applicable to the display units of these electronic apparatuses.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 illustrates a pixel equivalent circuit of an electro-optical device according to an embodiment of the present invention.

[Fig. 2]

Fig. 2 illustrates a pixel arrangement of an electro-optical device according to an embodiment of the present invention.

[Fig. 3]

Fig. 3 illustrates a driving method for an electro-optical apparatus according to an embodiment of the present invention.

[Fig. 4]

Fig. 4 illustrates a driving method for an electro-optical apparatus according to an embodiment of the present invention.

[Fig. 5]

Fig. 5 illustrates a driving method for an electro-optical apparatus according to an embodiment of the present invention.

[Fig. 6]

Fig. 6 illustrates the current characteristics of a luminescent element according to an embodiment of the present invention.

[Fig. 7]

Fig. 7 illustrates part of a manufacturing process for an electro-optical device according to an embodiment of the present invention.

[Fig. 8]

Fig. 8 illustrates part of a manufacturing process for an electro-optical device according to an embodiment of the present invention.

[Fig. 9]

Fig. 9 illustrates an example of an electro-optical device of an embodiment of the present invention applied to a mobile personal computer.

[Fig. 10]

Fig. 10 illustrates an example of an electro-optical device of an embodiment of the present invention applied to a display unit of a cellular telephone.

[Fig. 11]

Fig. 11 is a perspective view illustrating a digital still camera having a finder to which an electro-optical device of an embodiment of the present invention is applied.

[Reference Numerals]

V   power line

A   anode

L11   luminescent element

DT11   driving transistor

ST11   switching transistor

C11   capacitor

S1   first scanning line

S2   second scanning line

D1   first data line

D2   second data line

B   horizontal scanning period

B1   first horizontal scanning period

B2   second horizontal scanning period

B3   third horizontal scanning period

B4   fourth horizontal scanning period

SB   sub horizontal scanning period

SB1   first sub horizontal scanning period

SB2 second sub horizontal scanning period

SS(S1) scanning signal for first scanning line

SS(S2) scanning signal for second scanning line

SS(S3) scanning signal for third scanning line

DS(D1) data signal for first data line

DS(D2) data signal for second data line

DS(D3) data signal for third data line

E1 first luminescence period of pixel 11

E2 second luminescence period of pixel 11

E3 third luminescence period of pixel 11

Vsig control potential

IIep current value

1 glass substrate

2 poly-crystalline silicon layer

3 gate insulating film

4 gate electrode

5a p-type transistor

5b n-type transistor

6 first interlayer insulating film

7 source electrode and drain electrode

8 second interlayer insulating film

9 pixel electrode

10 adhesion layer

11 interlayer

12 electron-hole implantation layer

13 luminescent layer

14 anode

15 sealing layer